Thirty-day mortality and late survival with reinterventions and readmissions after open and endovascular aortic aneurysm repair in Medicare beneficiaries

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Objectives: **Late survival is similar after open and endovascular abdominal aortic aneurysm (AAA) repair (EVAR), despite a perioperative benefit with EVAR. AAA-related reinterventions are more common after EVAR, whereas laparotomy-related reinterventions are more common after open repair. The effect of reinterventions on survival, however, is unknown. We therefore evaluated the rate of reinterventions and readmission after initial AAA repair, 30-day mortality, and the effect on long-term survival.**

Methods: **We identified AAA-related and laparotomy-related reinterventions for propensity score-matched cohorts of 45,652 Medicare beneficiaries undergoing EVAR and open repair from 2001 to 2004. Follow-up was up to 6 years. Hospitalizations for ruptured AAA without repair and for bowel obstruction or ventral hernia without abdominal surgery were also recorded. Event rates were calculated per year and are presented through 6 years of follow-up as events per 100 person-years. Thirty-day mortality was calculated for each reintervention or readmission.**

Results: **Through 6 years, overall reinterventions or readmissions were similar between repair methods but slightly more common after EVAR (7.6 vs 7.0/100 person-years; relative risk [RR], 1.1; *P* < .001). Overall 30-day mortality with any reintervention or readmission was 9.1%. EVAR patients had more ruptures (0.50 vs 0.09 [RR, 5.7; *P* < .001]), with a mortality of 28%, but these were uncommon. EVAR patients also had more AAA-related reinterventions through 6 years (3.7 vs 0.9 [RR, 4.0; *P* < .001]; mortality, 5.6%), most of which were minor endovascular reinterventions (2.4 vs 0.2 [RR, 11.4; *P* < .001]), with a 30-day mortality of 3.0%. However, minor open (0.8 vs 0.5 [RR, 1.4; *P* < .001]; mortality, 6.9%) and major reinterventions (0.4 vs 0.2 [RR, 2.4; *P* < .001]; mortality, 12.1%) were also more common after EVAR than open repair. Conversely, EVAR patients had fewer laparotomy-related reinterventions than open patients (1.4 vs 3.0 [RR, 0.5; *P* < .001]; mortality, 8.1%) and readmissions without surgery (2.0 vs 2.7 [RR, 0.7; *P* < .001]; mortality 10.9%). Overall, reinterventions or readmission accounted for 9.6% of all EVAR deaths and 7.6% of all open repair deaths in the follow-up period (*P* < .001).**

Conclusions: **Reintervention and readmission are slightly higher after EVAR. Survival is negatively affected by reintervention or readmission after EVAR and open surgery, which likely contributes to the erosion of the survival benefit of EVAR over time. (J Vasc Surg 2011;53:6-13.)**

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Randomized trials and population-based studies have shown similar late survival after endovascular abdominal aortic aneurysm (AAA) repair (EVAR) and open AAA repair, despite an early perioperative benefit with EVAR.[1-5] Survival equilibrated by 18 months in randomized control trials and at approximately 3 years in Medicare beneficiaries.[1-3] Many theories have been proposed to explain the loss of survival benefit after EVAR.[6] Chance alone is unlikely given the consistent replication of these findings and the large size of the Medicare database.

The "survival of the fittest" theory holds that some of those who survive EVAR might not have survived open surgery. These patients tend to be older and more frail and thus more likely to die during the follow-up period.[3,6] A competing theory holds that rupture and reintervention are higher after EVAR and that these events will lead to increased late mortality after EVAR relative to open repair. We previously found, however, that the increase in AAA-related reintervention after EVAR is offset by an increase in laparotomy-related complications after open repair such as bowel obstruction and abdominal wall hernia, and that these complications also may have implications for late survival.[1]

To further explore this issue, we evaluated the rate of rupture, reintervention, and readmission for AAA-related and laparotomy-related complications after elective EVAR and open AAA repair in a previously defined cohort of propensity score-matched Medicare beneficiaries. We calculated the 30-day mortality associated with each type of event and plotted postoperative survival after EVAR and open repair, with and without reintervention or readmission.

METHODS

All traditional Medicare beneficiaries undergoing elective AAA repair from 2001 to 2004 were identified from Medicare administrative files. This primary data set has been used in prior analyses.[1] Patient demographic characteristics were identified from the Medicare denominator file. Comorbidities were identified from inpatient and outpatient claims up to 2 years before but not including the admission for repair. Reinterventions and readmissions were determined from inpatient and outpatient claims, and mortality was determined from the Medicare denominator file.

To control for the nonrandom assignment of patients to open repair vs EVAR, we created matched cohorts of patients using a logistic regression model from demographics and preexisting comorbidities predicting the likelihood of EVAR (propensity score). Our propensity score methods are described in detail in a prior publication.[1] For the current analysis, follow-up records were analyzed through 2007. Patient follow-up for reinterventions and readmissions ranged from 3 years to 7 years, based on the initial procedure year.

We identified all reinterventions and readmissions occurring in patients who survived >90 days. These were identified using Current Procedural Terminology (CPT, American Medical Association) and *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) coding (Appendix). In addition, we used a hierarchic schema within a single hospitalization, with major reinterventions superseding minor reinterventions. Admissions for ruptured AAA (with and without subsequent repair), AAA-related (major and minor), and laparotomy-related (major and minor) reinterventions and readmissions were recorded.

Major AAA-related reinterventions included conversion to open repair from EVAR, revision open repair, repair of an infected graft or a graft-enteric fistula, or an axillobifemoral or unifemoral bypass. Minor AAA-related reinterventions were divided into open and endovascular categories. Minor open reinterventions included iliac aneurysm repair, femorofemoral bypass, femoropopliteal aneurysm repair, thrombectomy, and embolectomy. Minor endovascular procedures included repeat EVAR, extension cuffs, iliac aneurysm repair, aortic or iliac angioplasty, and embolization procedures.

Major laparotomy-related reinterventions included small-bowel resection, large-bowel resection, and lysis of adhesions without bowel resection. Minor laparotomy-related reinterventions included ventral hernia repair. Hospitalizations for bowel obstruction or ventral hernia, without a subsequent operation, were also recorded. We defined age categories as 67 to 69, 70 to 74, 75 to 79, and ≥80 years. All readmissions with reinterventions for each patient were counted, not only first reinterventions, to determine the proportion of patients who had 0, 1, 2, or ≥3 reinterventions during follow-up.

Statistical analysis. We calculated the total number of reinterventions within each category as the total number per 100 patient-years based on a life-table analysis of patients surviving to each follow-up year. The 30-day mortality rates for each category of reintervention were calculated, as well as mortality ≤30 days of admission with a diagnosis of AAA rupture without subsequent repair or a laparotomy-related readmission without reintervention. Kaplan-Meier survival curves for long-term survival with and without subsequent reinterventions or readmissions were created for each repair method. Finally, we report the number of deaths secondary to a reintervention or readmission, occurring ≤30 days of any reintervention or laparotomy-related readmission, as a proportion of total deaths during follow-up.

Analyses were performed using SAS 9.1 software (SAS Institute Inc, Cary, NC). Reinterventions and readmissions are reported as raw numbers and as events per 100 person-years. Mortality rates are 30-day mortality from date of reintervention. Reinterventions and readmissions were compared with paired-sample *t*-tests. Kaplan-Meier survival was compared by χ^2 analysis. Statistical significance was defined as $P < .05$.

RESULTS

There were 61,598 patients who underwent elective AAA repair from 2001 to 2004. After propensity score matching we included 22,826 open repairs and 22,826 EVARs in our study sample.

Demographics for each repair method of patients with and without a reintervention or readmission during follow-up are presented in Table I. There were few significant clinical predictors of reintervention in either group. There was a statistical but not clinically significant age and gender difference. EVAR patients with a reintervention or readmission were less likely to have chronic renal disease but more likely to have coronary artery disease, without a recent revascularization, peripheral vascular disease, and hypertension. Open repair patients with an eventual reintervention or readmission were more likely to have coronary artery disease, peripheral arterial disease, chronic obstructive pulmonary disease, or end-stage renal disease.

Reinterventions: EVAR vs open repair. Reinterventions and readmissions were slightly more frequent after EVAR than open repair (7.56 vs 6.96/100 person-years, $P <$ .001; Table II). Rupture (with or without subsequent repair) was five times more common after EVAR (0.50 vs

Table I. Baseline demographics and comorbid conditions of Medicare beneficiaries with and without reinterventions or readmissions after endovascular and open aortic aneurysm repair, 2001-2004

	Endovascular repair			*Open repair*		
Variable	*Any reintervention*	*No reintervention*	P	*Any reintervention*	*No reintervention*	P
	(15.3%)	(84.7%)		(14.4%)	(85.6%)	
Male gender, %	79.0	80.5	<.05	81.3	80.5	.25
Age, mean ± SD	76.6 ± 5.3	76.2 ± 5.4	<.001	75.9 ± 5.2	76.3 ± 5.4	<.001
Comorbid conditions, %						
Myocardial infarction						
<6 months	2.0	1.9	.72	1.4	1.8	.10
≤6-24 months	8.1	8.0	.81	8.6	7.9	.13
Cardiovascular disease						
With CABG ≤24 months	4.6	4.4	.74	7.5	6.6	<.05
With PTCA ≤24 months	4.6	5.1	.20	4.4	4.9	.17
No recent intervention	22.1	19.6	<.001	19.4	17.5	<.01
Valvular heart disease	11.0	10.9	.89	11.0	10.4	.23
Congestive heart failure	14.0	13.2	.16	13.2	13.1	.86
Peripheral vascular disease	23.3	20.9	<.01	23.7	20.3	<.001
Cerebrovascular disease	15.6	16.5	.17	17.0	16.2	.23
Hypertension	67.9	65.9	<.05	66.2	65.7	.59
Diabetes mellitus	15.3	15.8	.47	15.2	15.8	.35
COPD	30.0	29.7	.68	33.4	29.1	<.001
Renal disease	3.1	4.1	<.01	3.8	4.0	.55
End-stage renal disease	0.8	0.8	.91	0.8	0.5	<.05

CABG, Coronary artery bypass grafting; *COPD*, chronic obstructive pulmonary disease; *PTCA*, percutaneous transluminal coronary angioplasty.

Table II. Total number of reinterventions and readmissions and rate per 100 person years for Medicare beneficiaries undergoing initial open and endovascular abdominal aortic aneurysm repair (*EVAR*), 2001-2004

	Through 6 years			
	EVAR		*Open*	
Variable	*No.*	*Rate*	*No.*	*Rate*
All reinterventions	6640	7.56	5991	6.96
Rupture	441	0.50	76	0.09
AAA-related reintervention	3222	3.67	798	0.93
Rupture repair	110	0.13	6	0.01
Major reintervention	362	0.41	149	0.17
Minor reintervention	2750	3.13	643	0.75
Minor open	655	0.75	463	0.54
Minor endovascular	2095	2.38	180	0.21
Laparotomy-related reinterventions	1218	1.39	2616	3.04
Major	968	1.10	1300	1.51
Minor	250	0.28	1316	1.53
Hospitalization for bowel obstruction or ileus w/o surgery	1736	1.98	2340	2.72

0.09 events/100 person-years, $P < .001$) but with a relatively low rate overall. AAA-related reinterventions, including rupture repair, were more than three times more common after EVAR (3.67 vs 0.93, $P < .001$). Rupture repair was performed in 110 patients after EVAR compared with just 6 after open repair (0.13 vs 0.01 events/100 person-years, $P < .001$). Other major AAA-related reinterventions were also rare but were two times more common after EVAR (0.41 vs 0.17 events/100 person-years, $P < .001$). Minor endovascular and open AAA-related reinterventions also were more common after EVAR (2.38 vs 0.21 [$P < .001$] and 0.75 vs 0.54 [$P < .001$], respectively). Laparotomy-related reinterventions were more than twice as likely after open repair (3.04 vs 1.39 events/100 person-years; Table II). Major laparotomy-related reinterventions (1.51 vs 1.10 events/100 person-years, $P < .001$) and minor laparotomy-related reinterventions (1.53 vs 0.28 events/100 person-years, $P < .001$) were both higher after open repair, as were laparotomy-related hospitalizations for bowel obstruction or ileus without surgery (2.72 vs 1.98, $P < .001$). AAA-related laparotomy-related reinterventions or readmissions and rupture after open repair were highest within the first year of follow-up and decreased over time. Ruptures after EVAR were greatest in the second year of follow-up, only slightly declining in subsequent years (Fig 1).

For patients originally undergoing EVAR, 84.7% had no reinterventions or readmissions during the follow-up period compared with 85.6% of open repair patients ($P < .01$). Among patients with reinterventions or readmissions, 54% of EVAR patients vs 57% of open repair patients had only a single reintervention or readmission ($P = .21$), whereas 26% vs 25% had two ($P = .34$) and 20% vs 18% had three or more ($P = .18$).

After stratifying by age, those <70 years were less likely to have a reintervention or readmission after EVAR vs open repair (relative risk [RR], 0.87; $P < .05$; Table III). Patients aged 70 to 74 had a similar risk regardless of initial repair method (RR, 0.99; $P = .74$), and those aged 75 to 79 and ≥80 years who initially underwent EVAR were more likely to have a reintervention (RR, 1.14; $P < .001$) or readmission (RR, 1.21; $P < .001$). Rupture and

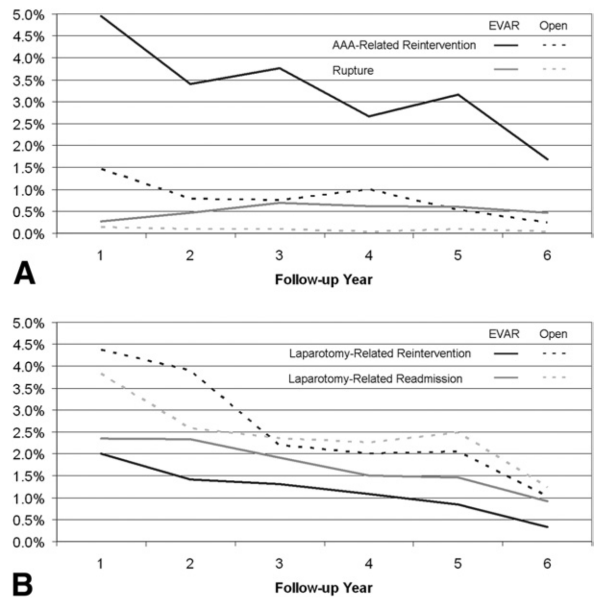

Fig 1. Reintervention and readmission rates through 6 years of follow-up for Medicare beneficiaries undergoing initial open and endovascular abdominal aortic aneurysm (*AAA*) repair (*EVAR*). **A,** AAA-related reinterventions and AAA rupture. **B,** Laparotomy-related reinterventions and readmissions.

rupture repair were more frequent after EVAR for all ages. AAA-related reinterventions were more common after EVAR, and laparotomy-related reinterventions and readmissions were significantly more likely after open repair across all age groups.

It was more likely that patients requiring a reintervention or readmission were older (≥75 vs <75 years) after EVAR (RR, 1.38; $P < .001$) and open repair (RR, 1.13; $P < .001$). Relative risks of all subsets of reintervention or readmission for patients aged ≥75 years compared with those <75 years for both EVAR and open repair are presented in Table IV.

Thirty-day mortality after reinterventions. Deaths ≤30 days of reinterventions or readmissions accounted for 9.6% of all EVAR deaths and 7.6% of all open repair deaths in the follow-up period ($P < .001$). The 30-day mortality for any reintervention or readmission was 9.1% (Table III). The highest 30-day mortality was for a diagnosis of rupture (27.7%), with 30-day mortality of rupture with repair at 30.2%. Other major AAA-related reinterventions had a mortality of 13.7%, whereas minor AAA-related reinterventions had a mortality of 4.2%. Minor open reinterventions had a mortality of 7.2%, whereas minor endovascular reinterventions had a lower 30-day mortality of 2.8%. Laparotomy-related reinterventions had a mortality of 8.5%. Split into major and minor categories, the major laparotomy-related reinterventions had mortality of 12.2%, and the minor laparotomy-related reinterventions had a mortality of only 3.1%. Hospitalizations for bowel obstruction or ileus without reintervention had a mortality of 10.9%. Mortality increased with age for all reintervention and readmission categories, with the exception of rupture and rupture repair, where patients aged 71-75 had the lowest mortality.

After exclusion of deaths ≤90 days of the original AAA intervention, patients with a reintervention or readmission after originally receiving EVAR had a decreased survival compared with those without. Similarly, after open AAA repair, patients who needed a reintervention or readmission had a lower long-term survival (Fig 2).

DISCUSSION

Although AAA-related reinterventions were more frequent after EVAR, most of these were minor endovascular reinterventions with relatively low 30-day mortality. Major AAA-related reinterventions and rupture, both with a high mortality, were uncommon for either repair method but were comparatively more frequent after EVAR. In contrast to AAA-related reinterventions, laparotomy-related reinterventions and readmissions were more common with open repair and also had relatively high mortality. The overall cumulative and long-term effect of these reinterventions and the higher rate of subsequent rupture after EVAR likely contribute to but do not fully explain the equalization of overall survival during the follow-up period after AAA repair, because 2% more deaths during follow-up were attributable to reinterventions and readmissions in the EVAR group compared with open repair. Given that the perioperative mortality predictors for all AAA repair include age, congestive heart failure, and renal failure, it is also true that these characteristics are more common in the EVAR cohort beyond the perioperative period and likely also contribute to a loss of survival benefit with EVAR.[7]

Two European randomized controlled trials included reinterventions in their follow-up outcomes analysis. However, the total numbers of patients treated were only 351 within the Dutch Randomized Endovascular Aneurysm Management (DREAM) trial and 1082 within EVAR I and thus had insufficient numbers of reinterventions for comparison with our findings.

The DREAM trial defined reinterventions as "any surgical or endovascular procedure performed after the primary aneurysm repair procedure and related to the aneurysm or the primary procedure, including incisional hernia repairs but exclusive of procedures involving superficial wound complications" and found that reinterventions by 9 months of follow-up were nearly threefold higher after EVAR than after open repair but became similar thereafter. The rate of aneurysm-related death still remained lower after EVAR up to 2 years.[3]

Similarly, the EVAR I trial found a reintervention rate of 6.9/100 person-years in the EVAR group and 2.4/100 person-years in the open repair group. These reinterventions after EVAR included those for type 1 (17) and type 2 endoleaks (17), "other surgery required" (13), graft thromboses (10), type 3 and unspecified endoleaks (8), graft migrations (7), graft rupture (3), and graft infection (1). Reinterventions after open repair were predominately

Table III. Rate per 100 person-years and relative risk of reintervention or readmission after endovascular (*EVAR*) vs open abdominal aortic aneurysm (*AAA*) repair in Medicare beneficiaries and 30-day mortality

Variable	*Reintervention rate* EVAR	*Reintervention rate* Open	*Relative risk EVAR vs open*	P *value*[a]	*30-day mortality (%)*
All reinterventions	7.56	6.96	1.09	<.001	9.1
Age, years					
67-69	4.90	5.60	0.87	<.05	6.3
70-74	6.86	6.93	0.99	.74	7.9
75-79	6.90	6.03	1.14	<.001	10.1
≥80	12.00	9.96	1.21	<.001	13.6
Rupture	0.50	0.09	5.69	<.001	27.7
AAA-related reintervention	3.67	0.93	3.96	<.001	6.2
Rupture repair	0.13	0.01	17.97	<.001	30.2
Major reintervention	0.41	0.17	2.38	<.001	13.7
Minor reintervention	3.13	0.75	4.19	<.001	4.2
Minor open	0.75	0.54	1.39	<.001	7.2
Minor endovascular	2.38	0.21	11.41	<.001	2.8
Laparotomy-related reinterventions	1.39	3.04	0.46	<.001	8.5
Major	1.10	1.51	0.73	<.001	12.2
Minor	0.28	1.53	0.19	<.001	3.1
Hospitalization for bowel obstruction or ileus w/o surgery	1.98	2.72	0.73	<.001	10.9

[a]Values of $P < .05$ are statistically significant.

Table IV. Relative risk of reintervention or readmission for patients aged ≥75 years vs those <75 years after endovascular abdominal aortic aneurysm (*AAA*) repair (*EVAR*) and open repair

Variable	*Relative risk ≥75 vs <75* EVAR	*Relative risk ≥75 vs <75* Open	P *value*[a] EVAR	P *value*[a] Open
All reinterventions	1.38	1.13	<.001	<.001
Rupture	2.41	2.05	<.001	<.01
AAA-related reintervention	1.53	0.75	<.001	<.001
Rupture repair	3.06	1.67	<.001	.55
Major reintervention	0.96	0.94	.66	.71
Minor reintervention	1.59	0.71	<.001	<.001
Minor open	1.10	0.66	.21	<.001
Minor endovascular	1.79	0.87	<.001	.36
Laparotomy-related reinterventions	1.18	1.03	<.01	.38
Major	1.27	1.32	<.001	<.001
Minor	0.89	0.82	.36	<.001
Hospitalization for bowel obstruction or ileus w/o surgery	1.24	1.41	<.001	<.001

[a]Values of $P < .05$ are statistically significant.

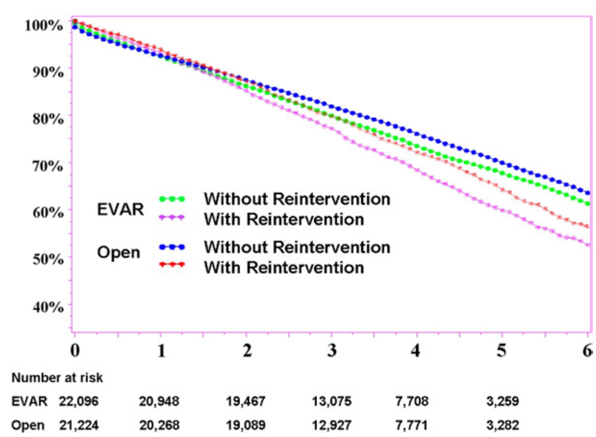

Fig 2. Long-term survival in Medicare beneficiaries with and without reinterventions after initial open or endovascular aneurysm repair (*EVAR*). Standard error <10% throughout.

"re-exploration of open repair" (16) and "other surgery required" (16).[2]

The Open Versus Endovascular Repair (OVER) Veterans Affairs Cooperative Study Group recently reported 2-year outcomes of 881 patients randomized to open or EVAR. They reported reinterventions including any unplanned surgery ≤30 days of AAA repair or any aortoiliac procedures at any time during follow-up. They found no differences between the two treatment groups, with 55 secondary procedures after open repair and 61 after EVAR. The most common secondary procedure after open repair (24 of 55) was incisional hernia repair, whereas the most common procedure after EVAR (42 of 61) was an endovascular procedure.[8]

The overall rate of reinterventions we found after EVAR was similar to that shown in EVAR I. Our current study, however, included a broader range of laparotomy-related complications and thus was able to identify more procedure-related reinterventions and readmissions after open repair. Given the high mortality associated with major laparotomy-related complications, this is an important consideration. It should be noted, however, that when patients were stratified by age, only patients ≥75 years had a higher rate of reintervention after EVAR, whereas patients <70 years actually had a higher rate of reintervention after open repair. We have previously shown that older patients had an increased perioperative survival advantage with EVAR compared with younger patients.[1] A higher reintervention rate may be considered acceptable for the elderly with EVAR given high risks with open repair. As reported in Table IV, patients who required a reintervention or readmission during follow-up were more likely >75 years, indicating that older patients are also more likely to require multiple reinterventions or readmissions.

The greatest number of reinterventions after EVAR fell into the "minor endovascular AAA-related" category. As Brewster et al[9] showed, most reinterventions after EVAR are catheter-based interventions. These carry a lower mortality in this population, with a 30-day mortality of 4% compared with 13.7% mortality for major AAA-related reinterventions. Thus, the overall effect on long-term outcome is not as substantial.

Rupture and rupture repair were more frequent after EVAR (0.5 vs 0.09/100 patient-years). The European Collaborators on Stent-Graft Techniques for Aortic Aneurysm Repair (EUROSTAR) group found an annual rate of rupture after EVAR of 1% in their early studies, with more occurring in the first year of follow-up (1.4%) than in the second year (0.6%).[10] Updated data from the EUROSTAR registry has shown a lower rate of rupture of 0.5% annually. Grafts subsequently removed from the market (and not available in the United States) had the highest rates of rupture and reintervention.[11,12] In the current study, the first year of follow-up had the lowest rate of rupture (0.27) compared with later years (range, 0.46-0.69). EVAR I had an overall rupture rate of 1.7% after EVAR and no ruptures after open repair with up to 4 years of follow-up.[2] In the current data set, given the trends of rupture rate during follow-up (Fig 1, *A*), it is possible that with longer follow-up the differences between repair methods would be more substantial.

Laparotomy-related reinterventions and readmissions, with 30-day mortality >10%, make up most of the reinterventions and readmissions after open repair. Admissions for laparotomy-related reinterventions after EVAR are unlikely to be related to the AAA repair and instead reflect the baseline rate in this elderly population. The relative increase in laparotomy-related reinterventions after open repair therefore represents the effect of laparotomy for AAA repair. This is probably underestimated as well because we did not adjust for prior laparotomy in our propensity score matching. This likely introduced bias against EVAR because prior laparotomy probably pushes repair selection toward EVAR.

Our analyses are subject to several limitations. The strengths of the 100% Medicare sample are its large size, longitudinal design, and broad representation of United States patients. The limitations are those inherent to administrative data such as coding error and lack of clinical detail. An example of this is that the mortality with rupture repair is higher than that for rupture without repair, implying that patients diagnosed with ruptured AAA during follow-up may not have true ruptures. We attempted to minimize coding discrepancies by using both hospital and physician claims as well as both inpatient and outpatient data, which provide verification and also allow for greater procedural detail and specificity of comorbid diagnoses.

Patients with a diagnosis of peripheral arterial disease were more likely to have a reintervention or readmission, but we also did not identify prior surgical procedures for lower extremity peripheral arterial disease, which may further predispose patients to some of the AAA-related reinterventions we used as outcomes. This likely would affect both repair groups equally, however.

Finally, we were unable to assess anatomic differences among patients and, unfortunately, could not evaluate these criteria for risk of reintervention or readmission within this study. Larger aneurysm diameter has been shown to be a risk factor for reintervention, as has severe neck angulation.[13,14] Patients who are not candidates for open repair but have large aneurysms deemed to be at high risk for rupture may have been offered EVAR even with less than ideal anatomy with that the mortality and reintervention rates may be higher but still within an acceptable margin given the risk without surgery. Given the age related increase in reintervention rates, this seems likely.

CONCLUSIONS

Late survival is worse in those undergoing reintervention or readmission after EVAR or open repair. Among initial AAA repair survivors, reintervention and readmission are slightly more common after EVAR than open repair and likely contribute somewhat to the loss of the early survival advantage seen with EVAR. However, reinterventions do not fully account for the survival curves coming together after 3 years. AAA-related reinterventions are more common after EVAR, but typically are minor endovascular reinterventions, whereas laparotomy-related reinterventions are more common after open repair. Future work should attempt to identify predictors of reintervention or readmission to factor this into clinical decision algorithms.

AUTHOR CONTRIBUTIONS

Conception and design: KG, BL, PC, AO, FP, MS
Analysis and interpretation: KG, BL, PC, AO, MS
Data collection: PC
Writing the article: KG, PC, MS
Critical revision of the article: KG, BL, PC, AO, FP, MS
Final approval of the article: KG, BL, PC, AO, FP, MS
Statistical analysis: KG, PC, AO, MS
Obtained funding: KG, BL, MS
Overall responsibility: MS

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INVITED COMMENTARY

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Late secondary procedures have been the necessary baggage that endovascular operators and our patients were willing to shoulder for the putative benefits of lower morbidity, mortality, and early recovery after endovascular aortic aneurysm repair (EVAR). The study by Giles et al from the Harvard Medical School's Health Care Policy group has examined this important outcome measure as it relates to late survival. Two points are worth noting. First, late complications are an equal opportunity hazard for both endovascular and open repairs, albeit the types and magnitudes of these complications may be different. Second, these complications and their treatments negatively impact survival of these patients.

Early estimates of the cumulative risk of secondary procedures after EVAR ranged from 10% to 15% per year. This risk was progressive and did not plateau over time. However, it is encouraging to see that these rates may have been overestimated based on current Medicare data, even with the inclusion of hospital admissions that did not involve an intervention. Although mortality after open repair has been consistently <3% in most of the prospective studies, EVAR mortality has been shown to be even lower by at least half those figures. Yet, it is somewhat sobering that all of these gains made after the index repair are completely eliminated by a secondary intervention, whose mortality rates can exceed 10%. Furthermore, contrary to what had been suggested earlier in this decade, the presence of an endograft does not appear to be protective if the therapy fails and the aneurysm ruptures. This study may serve as the most compelling evidence to date for why one needs to do it right the first time, because the stakes are so much higher next time.

Nearly 10 years ago when endovascular repair was gaining acceptance as a viable first-line treatment for aortic aneurysms in the United States, economic considerations were intensely studied given the high cost of these devices compared with conventional surgical grafts. Now that the "physiologic cost" of late failures has been defined, the next step is to compare the economic costs of repeat interventions in this therapy, which will be the next important piece in defining the full fiscal impact of the initial repair and its subsequent maintenance.

APPENDIX

Current Procedural Terminology (*CPT*) and *International Classification of Diseases, 9th Revision, Clinical Modification* (*ICD-9*) codes corresponding to reinterventions and readmissions.

Surgical reintervention/ readmission	*CPT code*	*ICD-9-CM code*
Rupture diagnosis		441.3, 441.5
AAA-related reintervention		
Rupture repair[a]	35082, 35092, 35103	
Major reintervention		
Conversion to open repair from EVAR	34830, 34831, 34832	
Repair of infected graft/graft-enteric fistula	35907, 35870	
Open AAA repair	35081, 35102, 35646	
Axillofemoral/ axillobifemoral bypass	35654, 35621	
Minor reintervention		
Open		
Iliac aneurysm repair	35131, 35132	
Femoral-femoral bypass	35661	
Femoral-popliteal aneurysm repair	35141, 35151	
Thrombectomy	35875, 35876	
Embolectomy	34201, 34203	
Endovascular		
Endovascular AAA repair	34800, 34802, 34803	
	34804, 34805, 0078T	

Appendix Continued.

Surgical reintervention/ readmission	*CPT code*	*ICD-9-CM code*
	0080T, 0001T, 0002T	
Extension cuff	34825, 34826	
Iliac aneurysm repair	34900, 75954	
Angioplasty (aortic or iliac)	35472, 35473	
Embolization	37204	
Laparotomy-related reinterventions		
Major		
Bowel resection		
Small bowel	44202, 44203, 44120 44130, 44186, 44187	
Large bowel	44140, 44160, 44204 44213, 44188	
Lysis of adhesions without bowel resection	44005	
Minor		
Ventral hernia repair	49560, 49561, 49565 49566, 49568, 49569	
Hospitalization for ileus or bowel obstruction without surgery		560.1, 560.8
		560.9, 560.3 560.81, 560.89

AAA, Abdominal aortic aneurysm; *EVAR,* endovascular aneurysm repair.
[a]EVAR codes or open repair/revision codes combined with rupture diagnosis are also a criteria for this category.